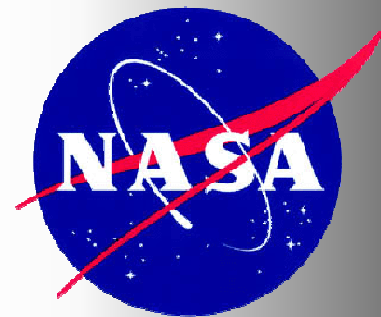


Carbon cycle uncertainties and observations

Dave Schimel

And

JPL Carbon and Climate Initiative Team



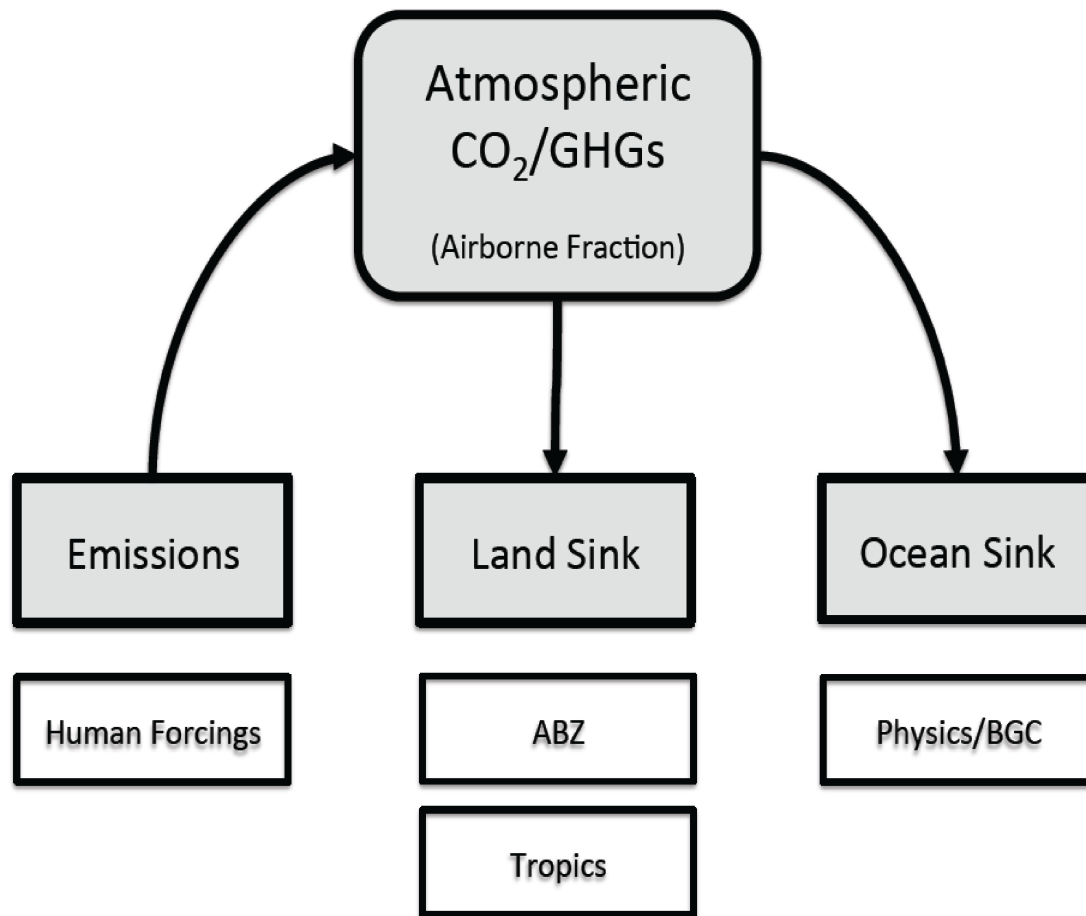
Way too much, way too fast



Model uncertainties

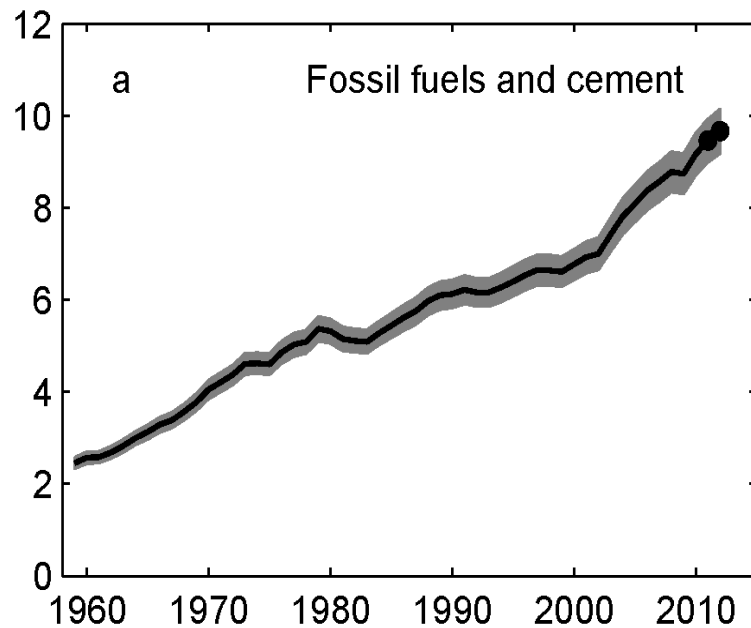
- What is the modern carbon budget?
- What processes result in the modern carbon budget?
- How will this change in the future?
- Existing data for benchmarking are grossly inadequate and do not constrain fluxes at critical scales.

Detection – attribution - prediction

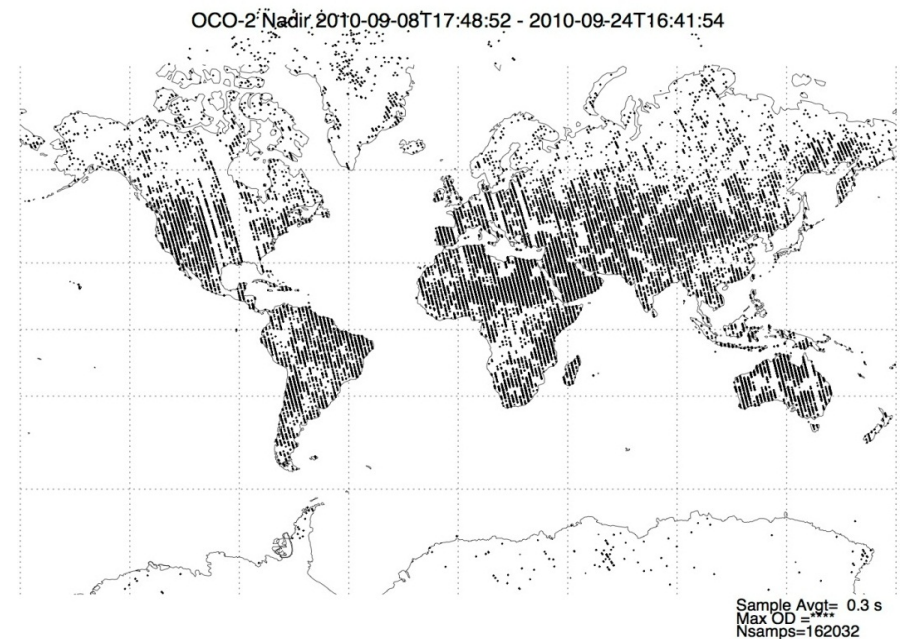
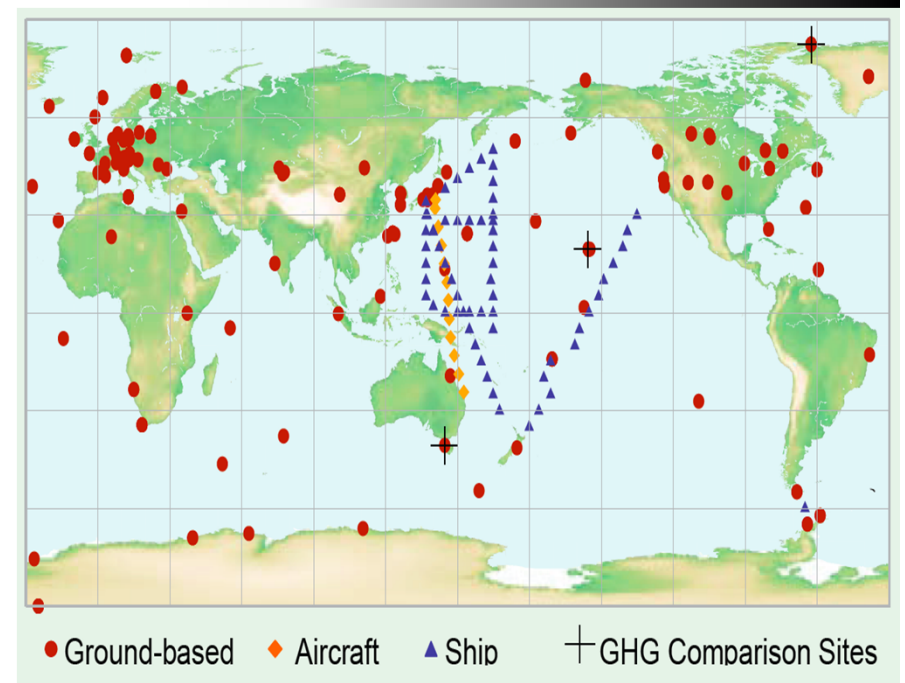


What
controls
the
airborne
fraction:
what will
cause it to
change?

Fossil emissions: growing uncertainty

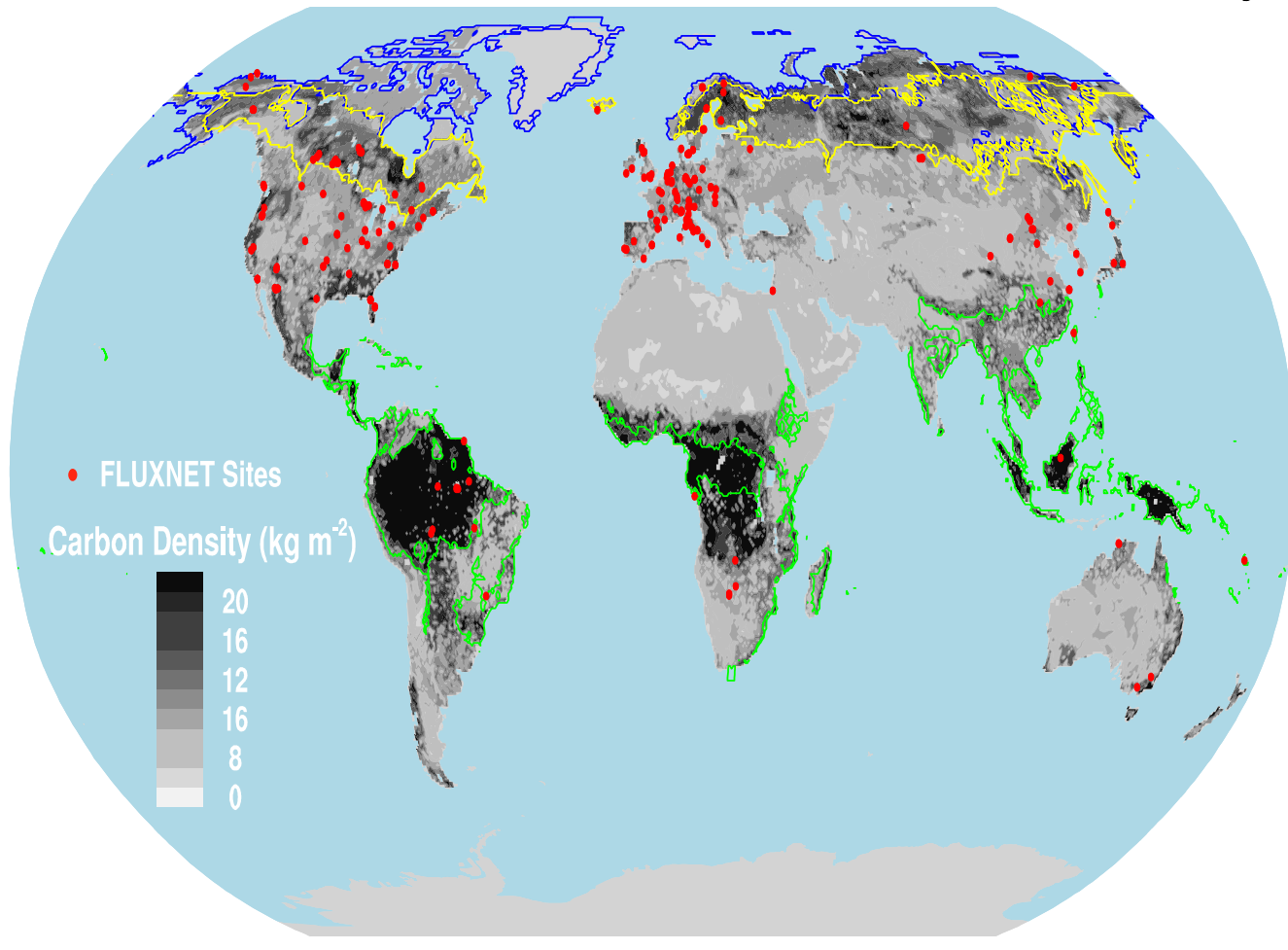


OCO-2 will collect ~380 Soundings/degree of latitude ($>10^6$ soundings/day). With Dave Keeling's flask sampling strategy that would be equivalent to 800 years of data.



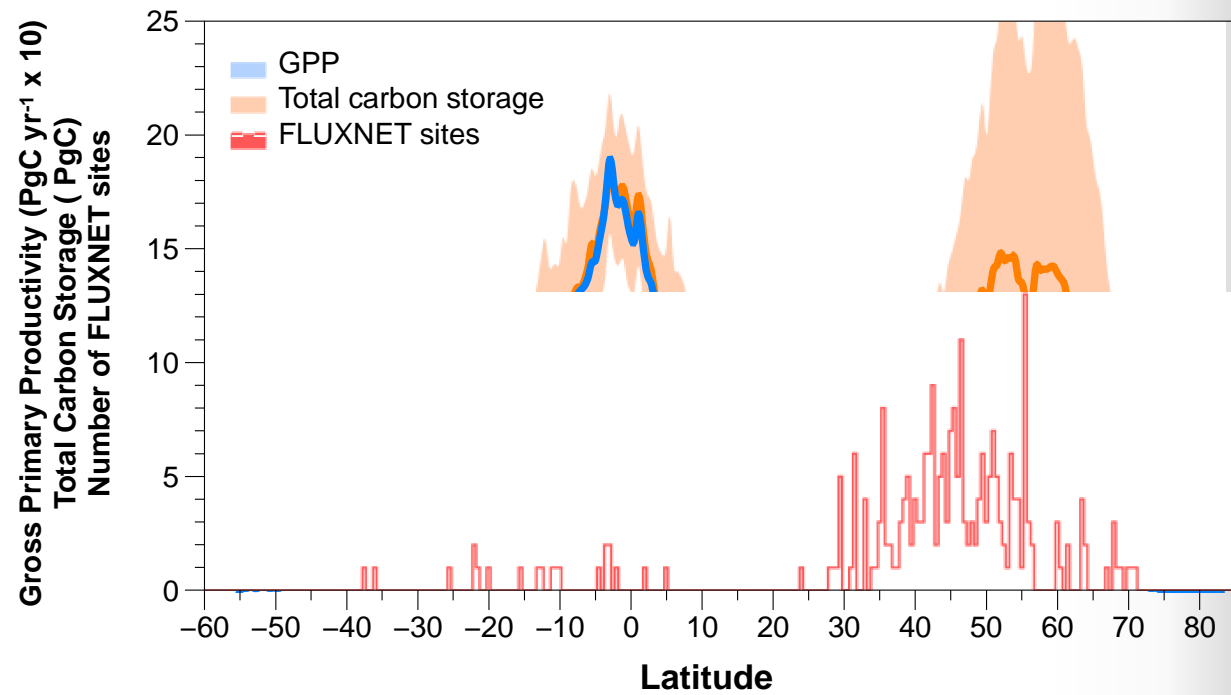
Framework

- Emissions from fossil and land use (forcing)
- $\beta(\text{CO}_2)$ = response to changing concentration (partitioned into land and ocean).
- γ (T, ppt, circulation...) = climate response (partitioned into land and ocean, further partitioned by climate term).

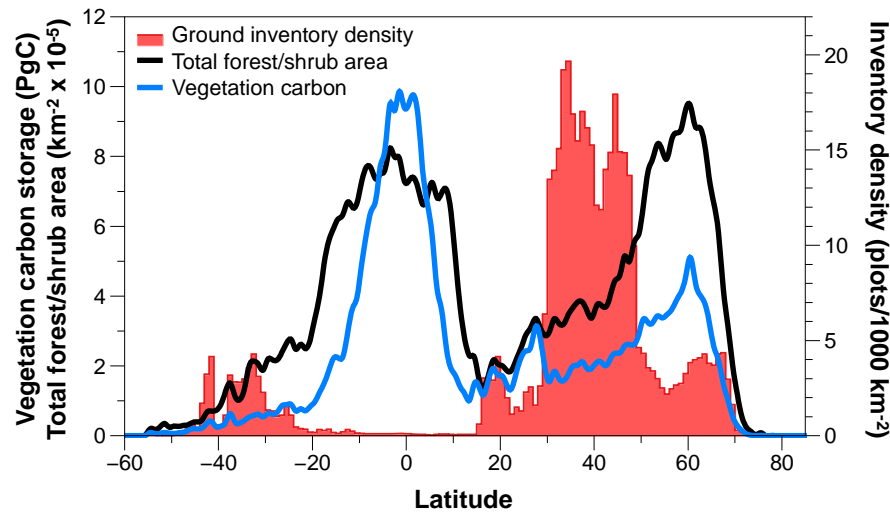


Terrestrial
“tipping
elements”
*The two
“poles” of
the
carbon
cycle*

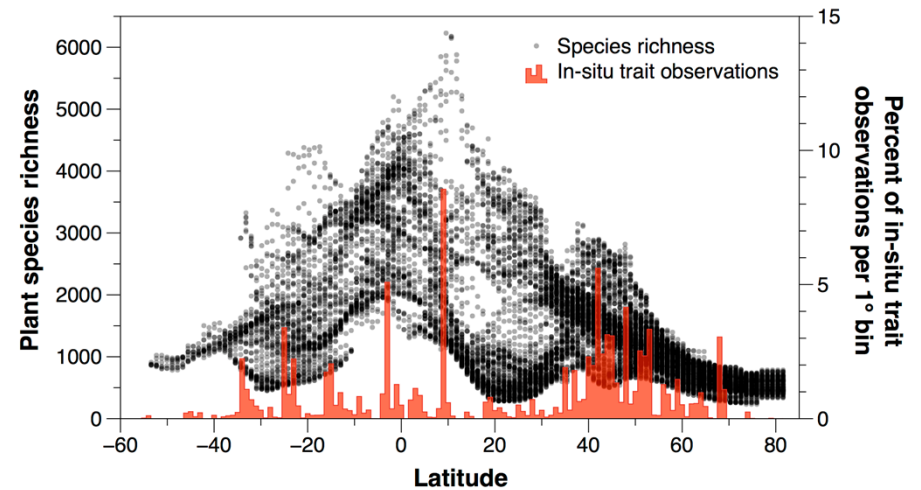
Data gaps



Fluxes

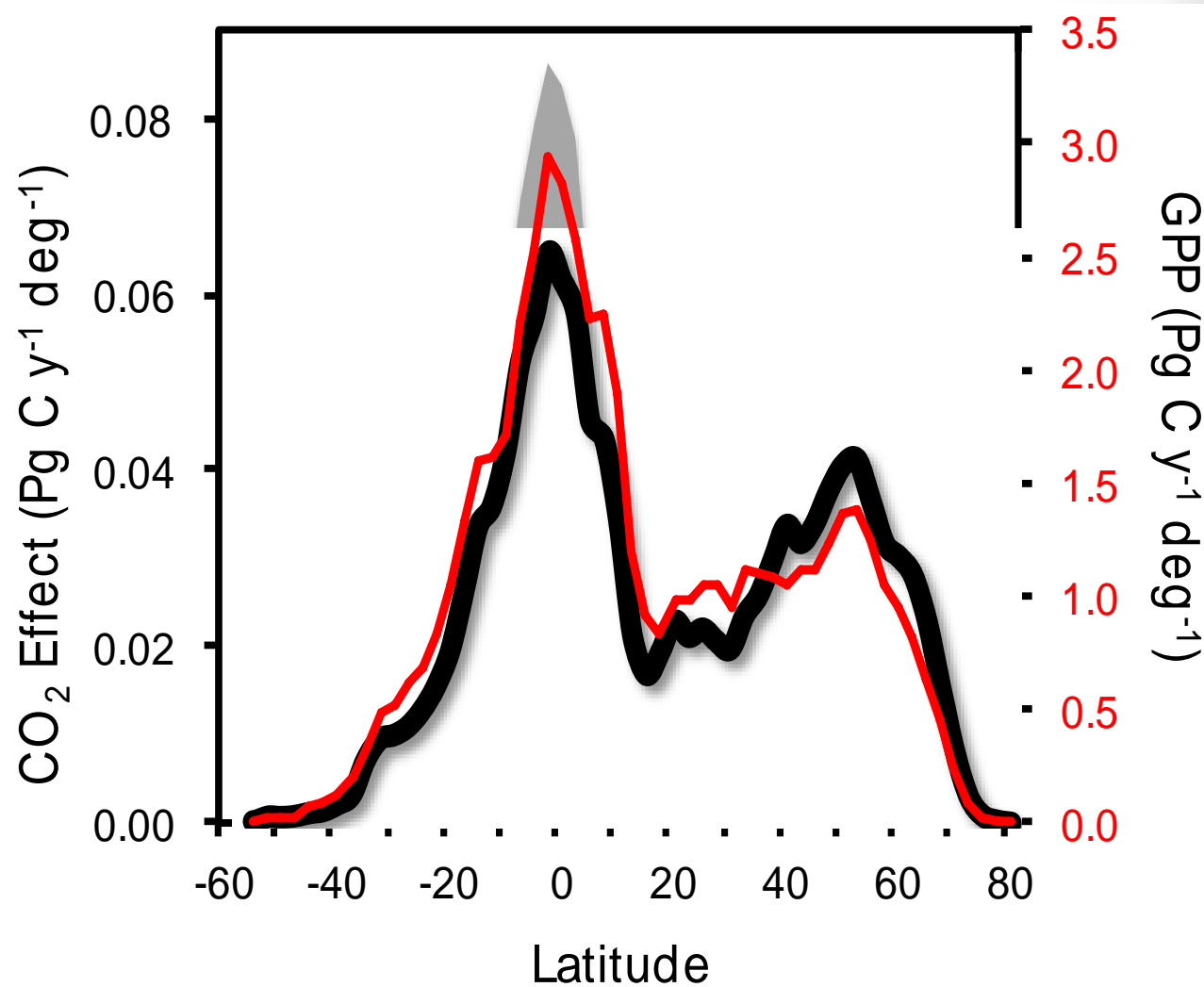


Stocks



Parameters

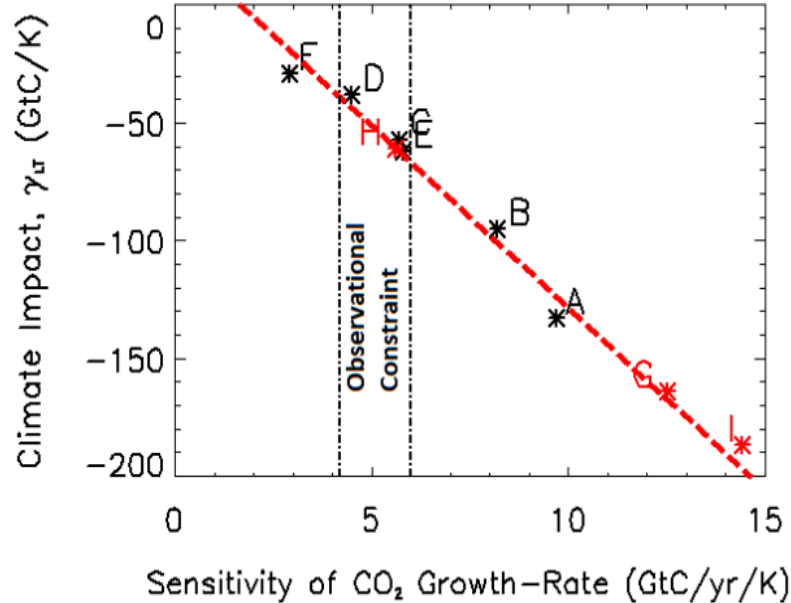
β



Key observations

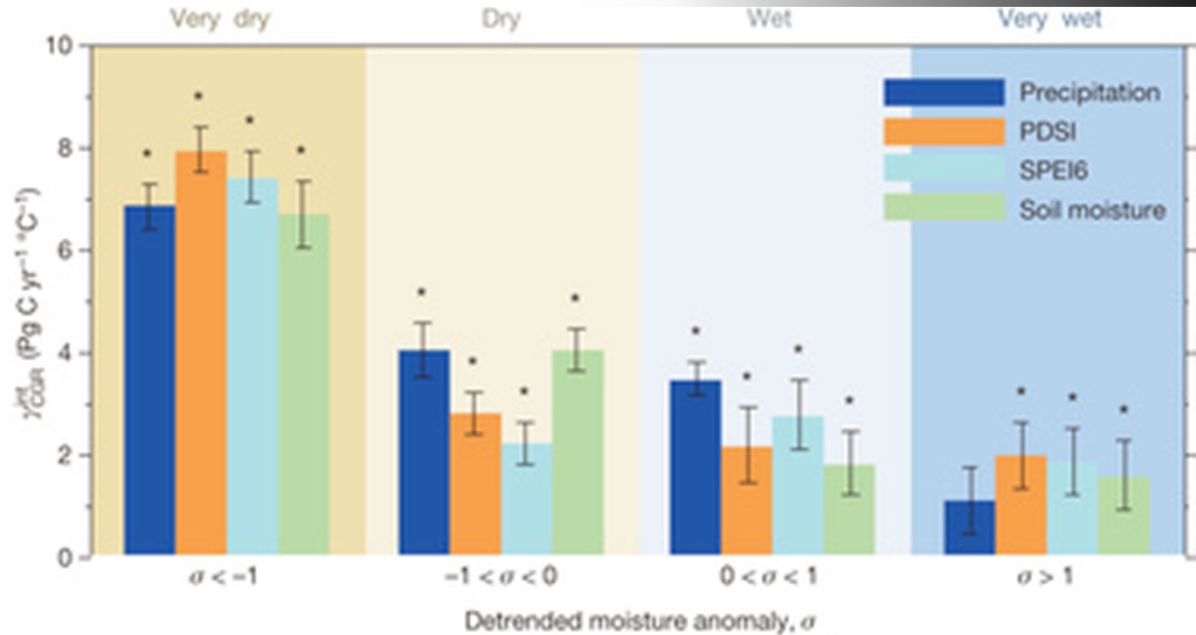
- GPP
- NEE
- Biomass
- Plant function
- Land cover

γ_{land}



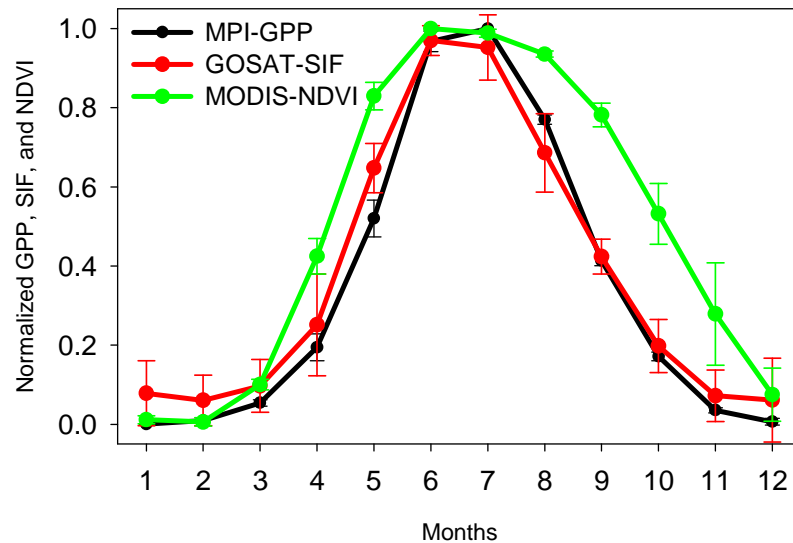
Key observations:

- GPP
- NEE
- Biomass
- LAI/FPAR
- Plant function
- Fire frequency
- Burned area
- Water stress
- Freeze-thaw

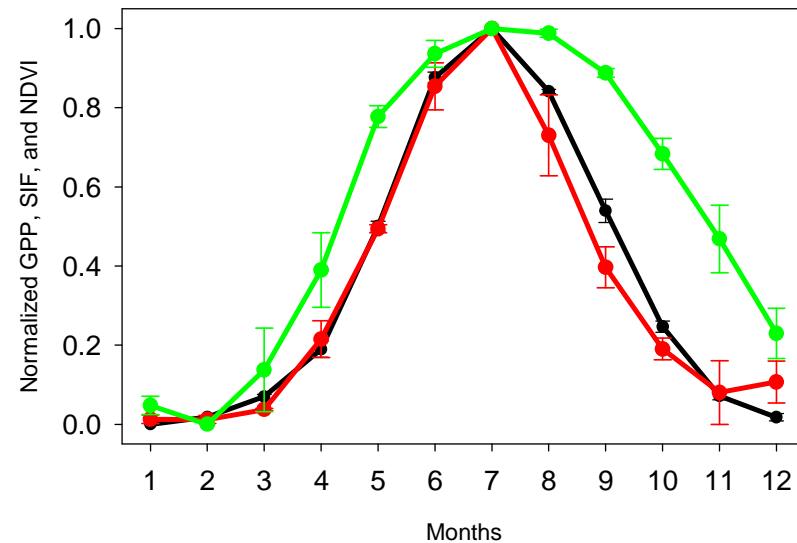


OCO-2-MODIS-SMAP γ products for CMIP6

Eurasia

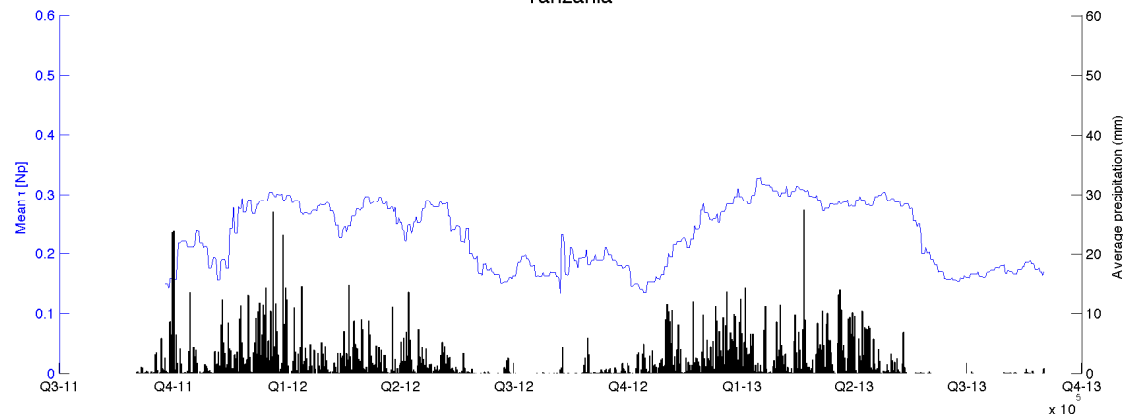


North America



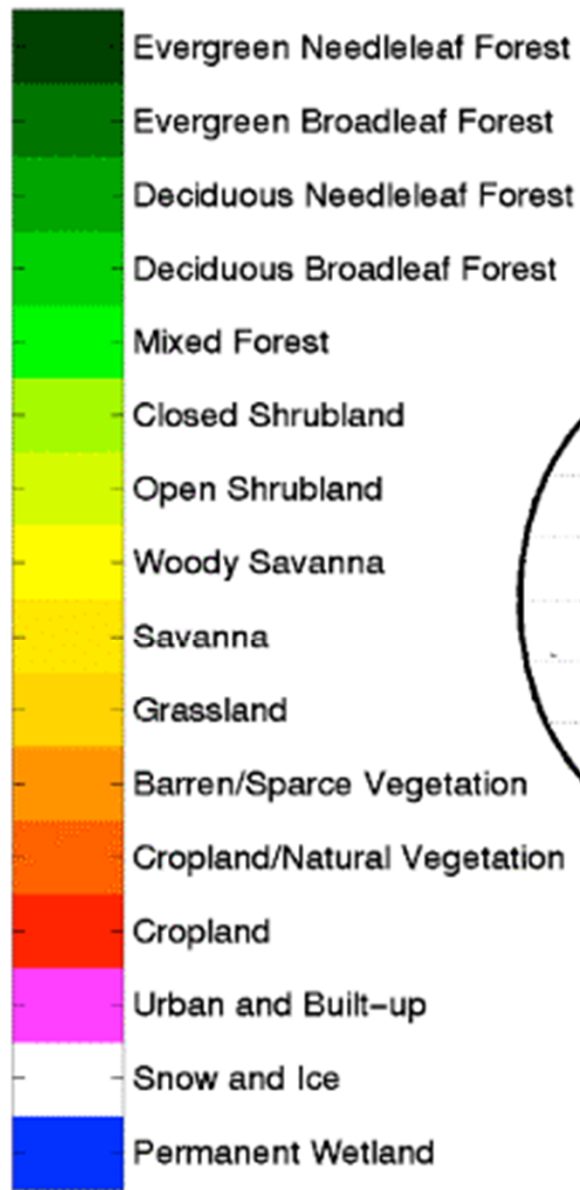
SIF is more sensitive to the seasonal and stress phenology than the VI alone, together they quantify structural and metabolic responses

Tanzania

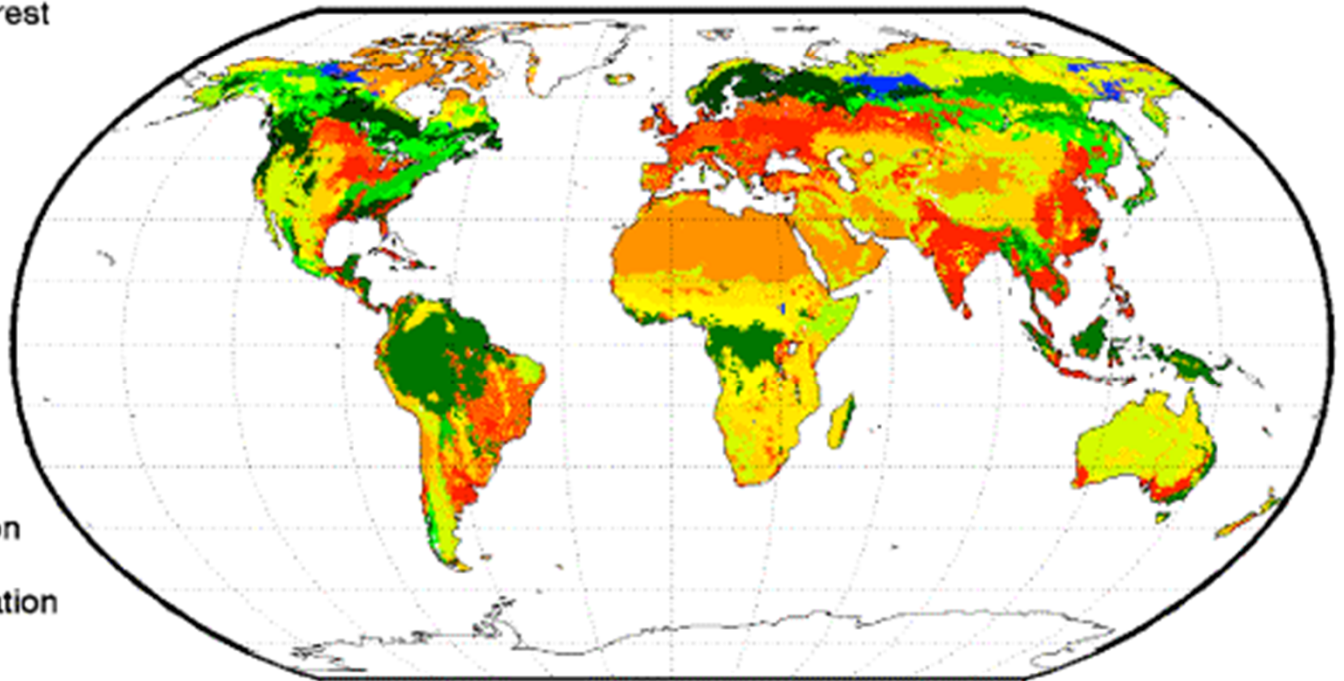


New μ wave measures may more directly quantify water stress

Terrestrial models depend on PFT-specific parameters



IGBP land cover types

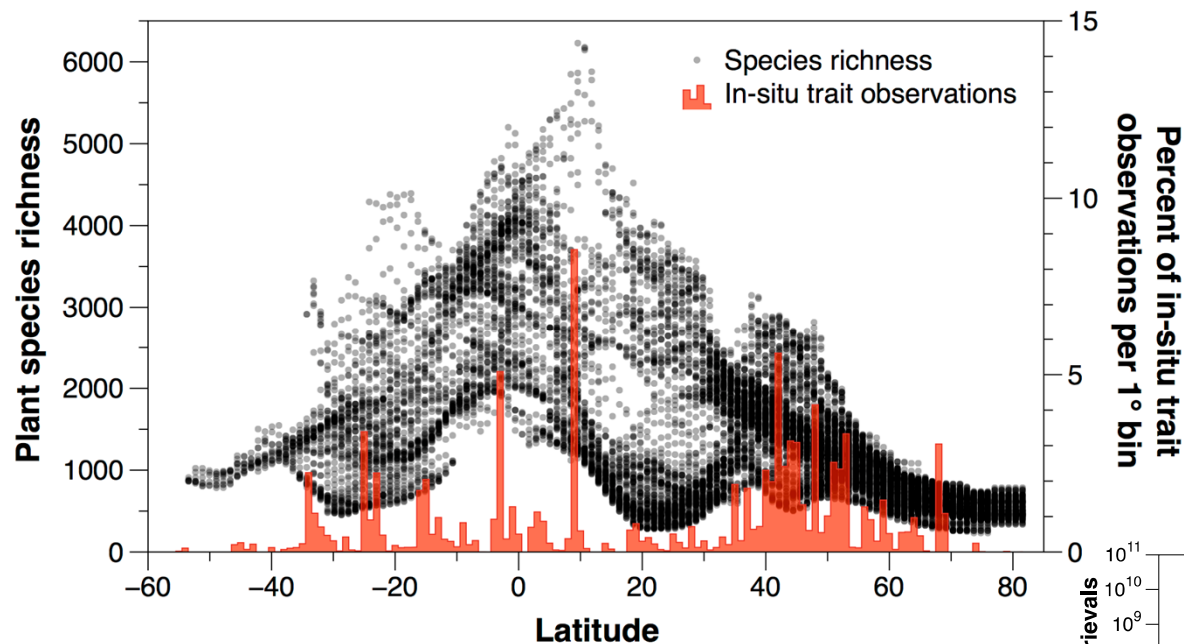


Biomes determine:

- Plant physiology (e.g., V_{max})
- Leaf and stem optical properties
- Roughness length
- Leaf and stem area index

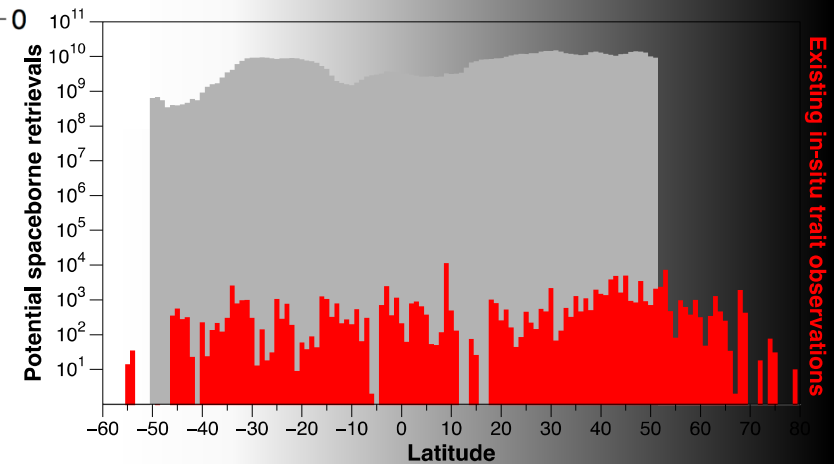
Plant functional types: CMIP6 improvements needed extrapolation using airborne as the near-term solution?

Currently ~20 globally, 16,000 species in the Amazon alone. Most key land model parameters depend on PFT definition.



Change in data density with
HyspIRI

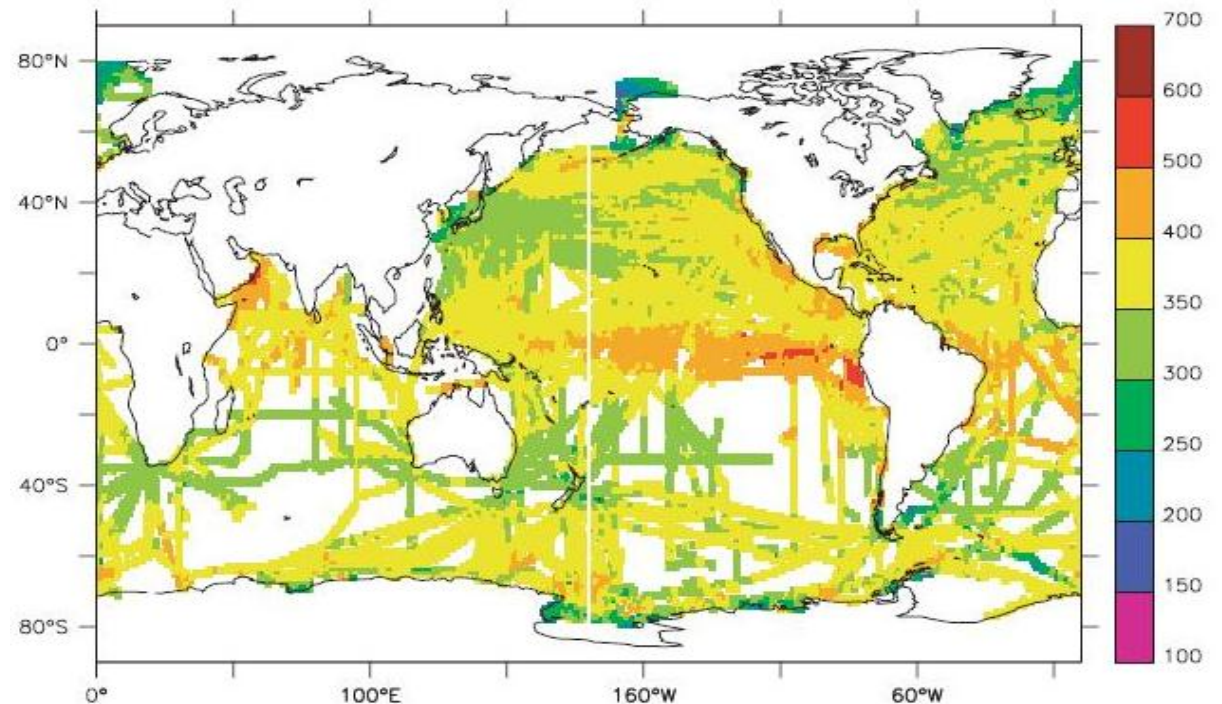
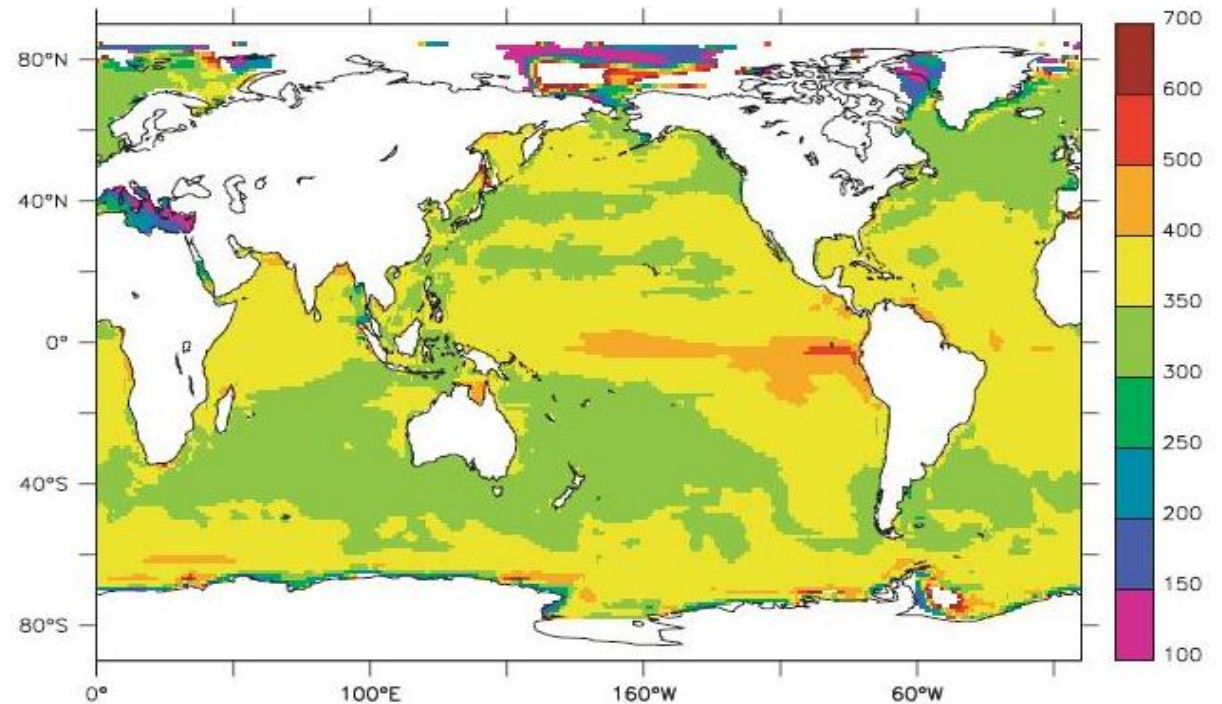
HyspIRI will increase the amount of
information from $10^2/\text{degree}$ to 10^8 .



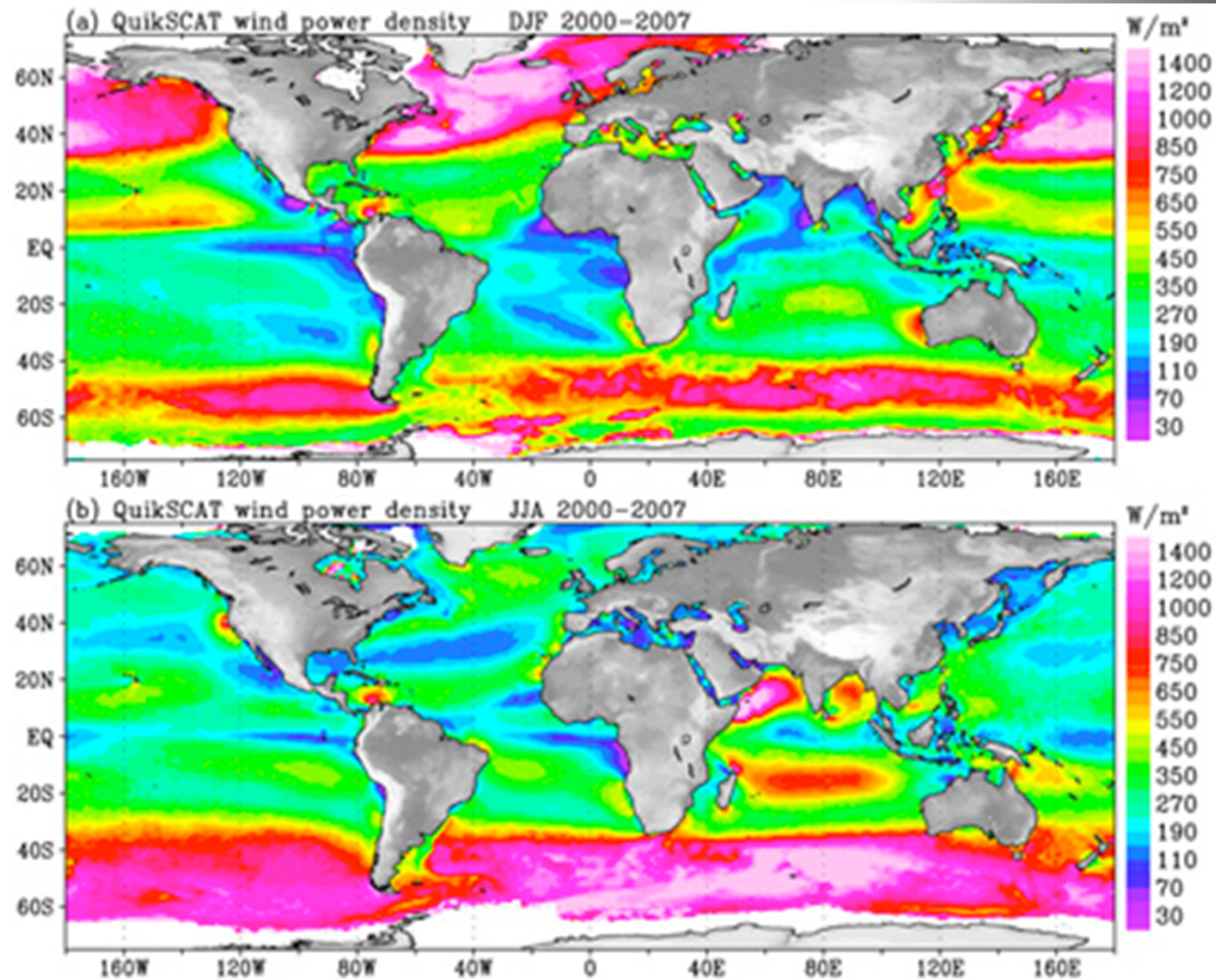
Ocean Carbon and $\Delta p\text{CO}_2$

Key data sets:

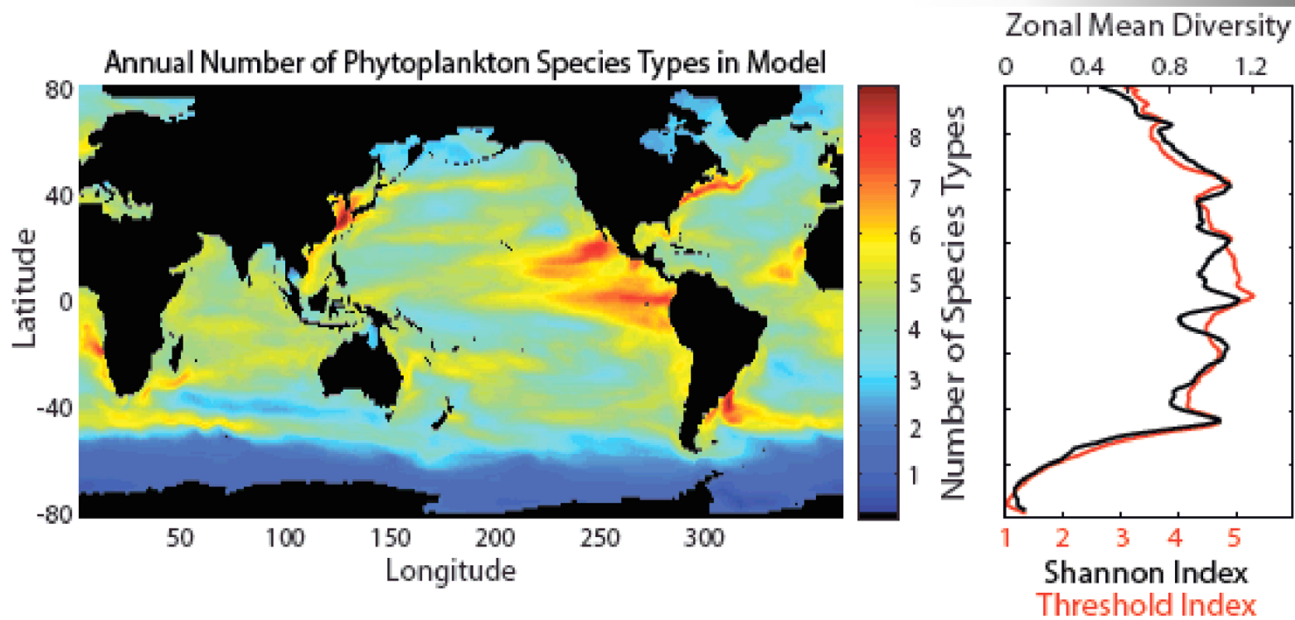
- SST
- Wind stress
- Topography
- Mixed layer depth
- Ocean color
- Fluorescence
- Functional diversity



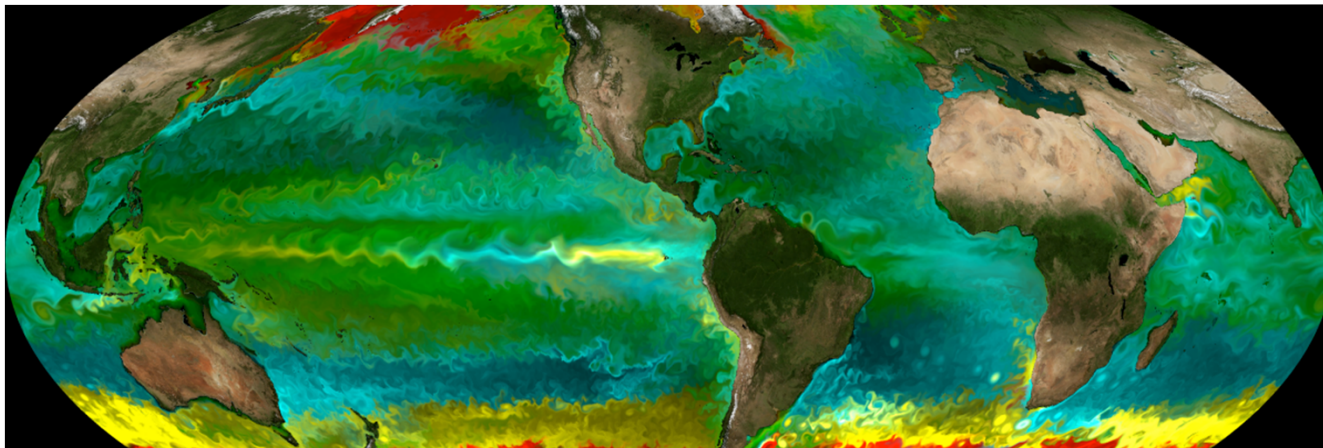
Wind Stress: a key driver of mixing



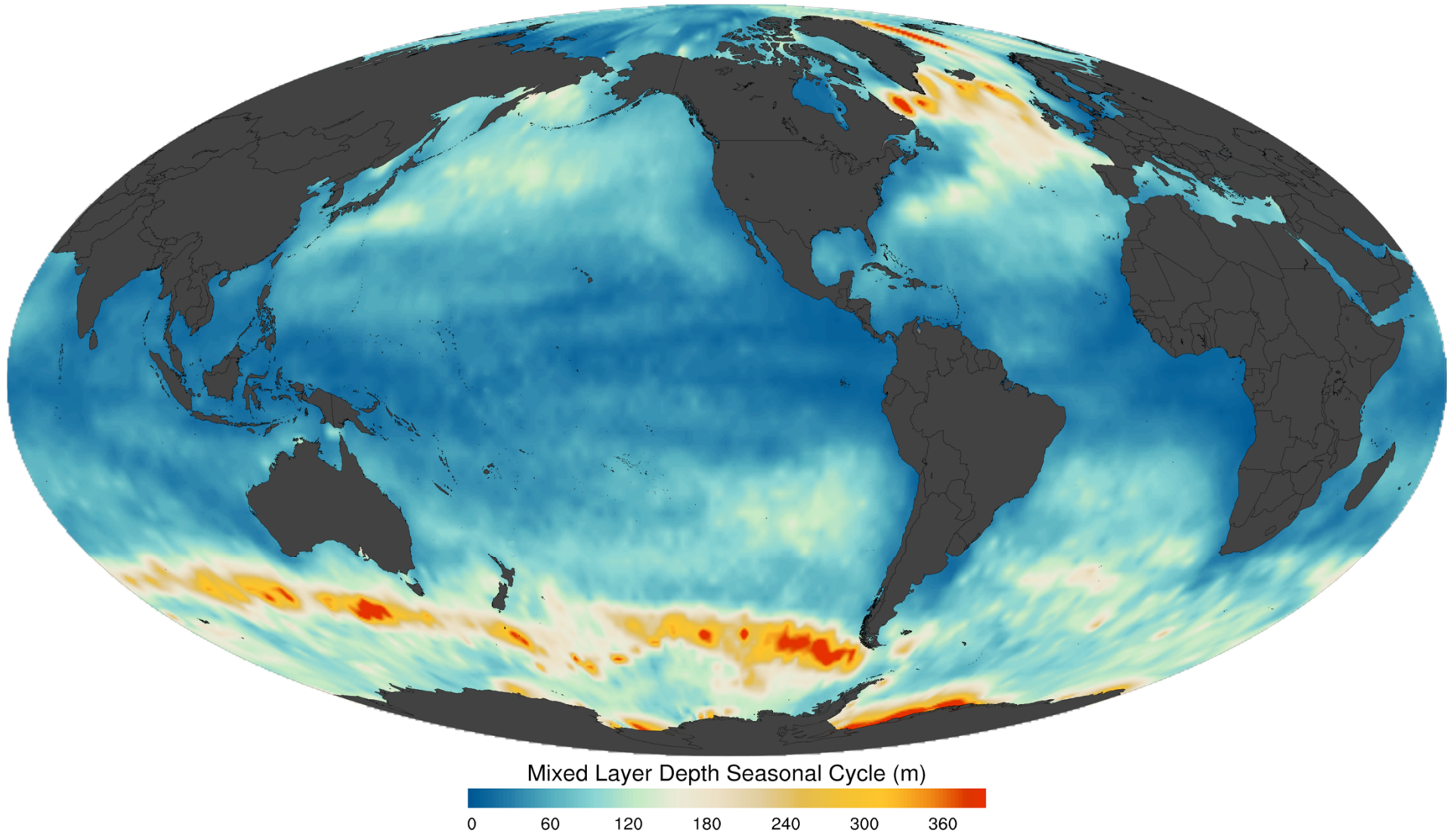
Ocean models increasingly make use of functional diversity



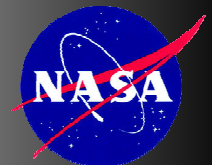
ECCO-
2/DARWIN



Mixed Layer Depth: differences between models are
related to major differences in ocean carbon uptake
CMIP5



Model process	Geophysical product	Observation
CO ₂	XCO ₂	OCO-2, GOSAT,
GPP (terrestrial)	GPP	MODIS, OCO-2
NEE	NEE	OCO-2 inversion
NEE/ET	Gridded NEE, ET	Eddy Covariance
Evapotranspiration	Skin temperature	MODIS, LANDSAT, HyspIRI
Fossil and cement	XCO ₂	OCO-2/3
Land use/land cover change	Area change, land cover, burned area, fire intensity	LANDSAT, MODIS
Biomass	Canopy height or volume scattering	ICESAT-2, BIOMASS
LAI/FPAR	Vegetation Index	MODIS
Plant function	V _{cmax} , LMA, N	HyspIRI
Water stress	Soil or canopy moisture, skin temperature	SMAP, Aquarius, SMOS, xSCAT
Temperature	Temperature	MODIS, LANDSAT
Productivity (marine)	Ocean color	MODIS, PACE
Phytoplankton functional diversity	Phytoplankton functional groups	PACE
SST	SST	MODIS
Wind stress	Wind stress	RapidSCAT
Vertical mixing	Vertical mass flux	Argo, assimilation-ECCO2
Mixed layer depth	Turbulence, temperature, light,	Argo, assimilation-ECCO2



Summary: data products from current and future missions